UNITED STATES AIR FORCE
MATERIALS TECHNOLOGY HIGHLIGHTS

Air Force Research Laboratory

Materials & Manufacturing Directorate

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Directorate Experts Ensure Air Force Flies High

Despite the best efforts of engineers, scientists, manufacturers and maintenance personnel to provide the safest aircraft systems possible, at times materials fail and systems malfunction. When this happens, materials experts from the Air Force Research Laboratory's Materials and Manufacturing Directorate try to determine what went wrong and work with their partners in aviation to find safe, reliable and affordable solutions.

The directorate's Materials Integrity Branch is comprised of experts in electronics failure analysis, structural failure analysis, nondestructive evaluation, coatings, composites, electrostatic discharge, and paints, sealers and adhesives. Over the years, this team has been called upon to solve hundreds of materials challenges.

Take aircraft wiring as an example. More than 20 miles of electrical wire snakes through a jet fighter and over 150 miles are in a bomber. This wiring provides a lifeline that connects electrical systems with the components used to operate the aircraft's flight navigation and communication systems. A short or failure anywhere in the wiring can have catastrophic consequences.

"The wire bundle insulation in many of the older aircraft, under certain conditions, can fail catastrophically," George Slenski, the branch's Electronic Failure Analysis Group leader explained. "An electrical short can rapidly propagate into adjacent wiring causing the loss of multiple systems. At times, this has led to major damage to aircraft wiring and required aircrews to declare emergencies. Most times the wiring failures result in aircraft downtime, which can greatly increase the maintenance burden that results from the troubleshooting and repair of aircraft."

The group's battle with aging wiring isn't limited to military and commercial aircraft. In 1999, the space shuttle lost two of its main engine controllers five seconds after it launched (back-up systems allowed the shuttle to complete its mission). The shuttle program was grounded and the National Aeronautics
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George Slenski (right) studies space shuttle wiring at the request of the National Aeronautics and Space Administration (NASA). Slenski, who worked as part of an independent assessment team, evaluated space shuttle maintenance practices and briefed them to NASA management.

Fuel Processor Technology Will Improve Remote Power Generation

Researchers at the Air Force Research Laboratory's Materials and Manufacturing Directorate are developing a Deployable Logistics Fuel Processor, which will permit the use of a reliable, and easily operated fuel cell power system as an alternative to current Mobile Electric Power units.

Replacing current Mobile Electric Power units with fuel cell technology, which uses hydrogen as the primary energy source, will allow light and quick deployment of this important infrastructure element.

Today's mission requires a "light and lean" Air Force to protect vital U.S. interests. They must be increasingly prepared to rapidly deploy and indefinitely sustain forces. Operations abroad require mobile, air deployable infrastructure elements to stage and support land and air operations in remote locations.

Mobile Electric Power (MEP) is one of the seven essential deployment infrastructure elements. Air Force bases overseas use MEP-12 generators, large 750 kilowatt (kW) generators driven by diesel engines, to provide electrical power. To support a contingent of 1,100 airmen, four 1,353 cubic foot MEP-12 generators, which individually weigh 25,734 pounds, must be deployed, one generator being a standby unit. This requires four transport aircraft and 4,000 gallons of fuel per day, which puts a severe burden on an already stressed air fleet.

Researchers from the directorate's Air Expeditionary Forces Technology Division have faced several challenges to developing fuel processor technology. Due to the potential pitfalls of sulfur content and coking while reforming heavy hydrocarbon fuels such as JP-8 and diesel, it has been difficult to effectively use battlefield logistic fuels as the primary energy source for fuel cells. Researchers with the division have developed a fuel processor capable of removing 99.98 percent of the sulfur that exists in fuel and producing ultra-clean hydrogen using hydrogen membrane technology. This reforming process also removes impurities such as carbon monoxide, carbon dioxide, and hydrogen sulfide.

In addition, the fuel processor that engineers have developed in the lab uses an efficient radiant burner and a compact microchannel evaporator to produce the high pressure and high temperature steam needed for the fuel reforming process. In order to recover water from fuel cell exhaust, which is 100 percent humid air, engineers also developed a compact condenser unit. The recovered water can be recycled and used for future reforming processes.

One of the Air Force's foremost goals in this effort is miniaturizing fuel processors for easy integration in a deployable system. Researchers suggest that an effective approach to reducing size and response time in fuel reformers is to combine catalytic steam reforming with microchannels technology in a slab configuration. Microchannels are small passages, less than 500 microns wide, that enhance the catalytic residence time, and heat and mass transfer. The technology is also compact and modular in design, which will allow its integration in both portable units and large electrical generators. Using micro-channels, researchers expect they can develop a logistic fuel processor with a volume of one cubic foot that will extract enough hydrogen needed by a fuel cell stack to produce 100kW of electricity. It clearly demonstrates the potential for out performing conventional MEP generators at a fraction of the size. Researchers expect to deliver a 10 kW fuel cell power generator by the end of 2005.

The rapid evolution of fuel cell technology as a replacement for conventional electric power generators provides the potential for future power systems that use hydrogen as their primary fuel. The fuel processor will provide the user with efficient, easily operable, highly reliable, on-demand production of hydrogen at bare base locations. The compact and modular power generator, which consists of the fuel processor and fuel cell, will result in a 16 percent reduction in deployment airlift requirements, and will offer lower emissions, infrared signature and noise levels, and a 50 percent reduction in power generation sustainment costs.

A Mobile Electric Power-12 (MEP) generator.

For more information, contact the Materials and Manufacturing Directorate's Technology Information Center at techinfo@afrl.af.mil or (937) 255-6469. Refer to item 01-295.

Laser Ultrasonic Technology Improves Composite Parts Inspections

A new aircraft composite parts inspection system, developed with support from the Air Force Research Laboratory Materials and Manufacturing Directorate, will reduce the time required to inspect composite parts by up to 90 percent.

The Laser Ultrasonic Technology (LaserUT ™) system, developed by Lockheed Martin Aeronautics Company with technical assistance from the directorate's Nondestructive Evaluation Branch, enables affordable, highly accurate, high-volume inspection of complex-contoured composite parts for next generation fighter aircraft.

Next generation fighter aircraft will have a high percentage of graphite-epoxy composite materials in their structures. This is because graphite epoxy materials offer a high strength-to-weight ratio and extended service life. Extensive inspection is required however, to ensure no flaws exist in the many layers that make up the finished components.

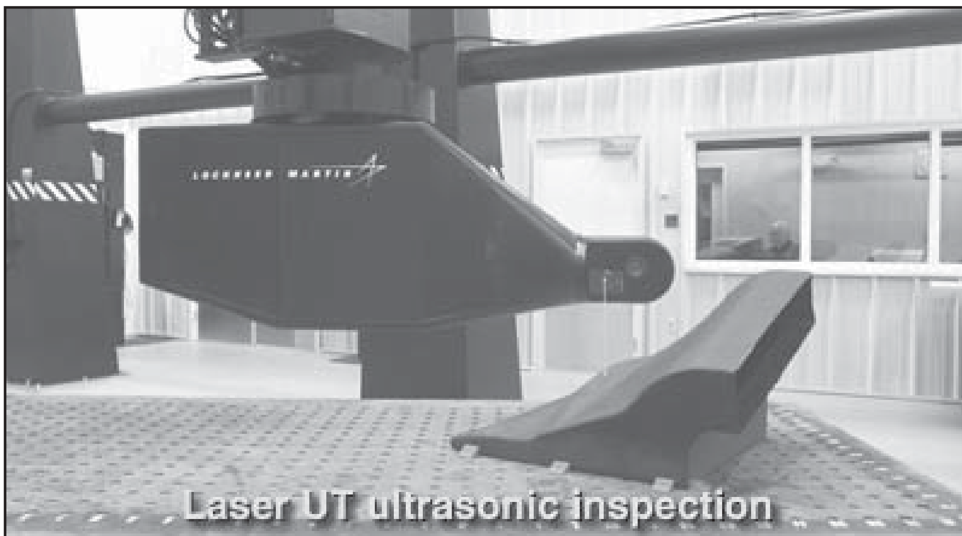
Lockheed Martin Aeronautics Company, with technical assistance from scientists and engineers in the Materials and Manufacturing Directorate's Nondestructive Evaluation Branch, began inspecting composite aircraft parts using the patented LaserUT™ inspection system. This effort marked the first time aircraft composite parts were inspected using the advanced laser testing system, following years of research and prototyping by Lockheed Martin Aeronautics and its predecessors.

LaserUT ™ effectively handles complex-contoured components up to 54-feet long, 27-feet wide and 21-feet high. The system is controlled by a supercomputer capable of advanced, real-time signal processing and data analysis, and also has a user friendly operator interface that provides state-of-the-art ultrasonic flaw detection. The system provides real-time feedback to the system operator, or design and process engineers, facilitating rapid configuration and process changes.

Lockheed Martin Aeronautics Company is continuing its research and development of the LaserUT ™ inspection system in an effort to further reduce inspection times and meet affordability requirements. LaserUT ™ is expected to save several hundred million dollars over the lives of next generation fighter aircraft programs due to greatly increased parts throughput. For example, using conventional parts inspection equipment, it takes about 24 hours to fully inspect a composite inlet duct on an advanced fighter aircraft. Using LaserUT™ technology, the time has been reduced to less than two hours, representing a 90 percent reduction in test cycle times.

LaserUT™ requires minimal set-up time and performs high-resolution, composite parts inspections in a fraction of the time required by conventional water ultrasonic inspection systems. Steep reductions in inspection times will shorten manufacturing span times by several weeks, resulting in major cost savings for the Department of Defense. The LaserUT™ inspection system's improved accuracy enables even higher standards of quality for the Air Force and commercial aerospace sector.

For more information, contact the Materials and Manufacturing Directorate's Technology Information Center at techinfo@afrl.af.mil or (937) 255-6469. Refer to item 01-185.



Shuttle Wiring

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and Space Administration (NASA) requested Slenski's input as part of an independent assessment team that evaluated space shuttle maintenance practices.

Experts from the wiring assessment team identified several issues that required immediate action prior to future flights. They inspected two of the shuttles, identifying ways to determine aged wire damage and steps to be taken when examining the entire shuttle fleet. They also identified pre-existing damage that may have been caused by earlier maintenance actions. The team briefed NASA management on their findings, which resulted in the wiring problems being corrected and the shuttle fleet returning to flight.

The Failure Analysis Group solves these problems related to aging wiring; studying the way a material would fail on the aircraft, and how it could propagate and cause extensive damage to the wiring. But Slenski said that the toughest part of his job begins when the analysis of a problem is complete.

"We have to clearly communicate the critical elements of our analysis to the group responsible for preventing possible future incidents. We also attempt to communicate in general terms our findings to the aerospace community through published reports and various briefings and presentations," Slenski said.

The group's efforts to communicate wiring related issues and to generate awareness of electronic failure analysis has established the Air Force Research Laboratory as the national research and development facility to turn to for solutions. In fact, senior officials from the Department of Defense and the White House Office of Technology and Policy requested that they participate on a team for defining national strategy in this critical area.

"The program that the White House has initiated will allow us to coordinate with the other DoD services, FAA and NASA to establish a national strategy for dealing with these issues," Slenski said. "This collaboration will help us to improve reliability and reduce the ownership costs of aircraft systems, proactively develop better diagnostic and prognostic tools for managing wiring, and to develop better materials for aircraft wiring.

"Taking these steps in the right direction together will ultimately decrease the amount of maintenance time required to maintain military and commercial aircraft and will improve our mission readiness," Slenski said.

Completed CONTRACTS

- Low Cost Carbon Foam Thermal Protection System - F33615-01-M-5025
- Carbon Nanotubes For Electromagnetic Packaging - F33615-01-M-5033
- Composite Affordability Initiative (CAI) Phase II Lockheed Martin - F33615-98-3-5105
- Rapidcoater For Laser Shock Peening - F33615-98-C-5116
- Parts Obsolescence Management Tools - F33615-98-C-5147
- LEANTEC (Lean Transition Of Emerging Industrial Capability) - F33615-97-2-5153
- Advanced Field Use Instrument For Nondestructive Evaluation Fatigue Damage Assessment and Remaining Service Life Prediction for Aging Aerospace Systems - F33615-99-C-5201
- Probe Technology For Low Observable Nondestructive Evaluation - F33615-00-C-5201
- Brazed Aluminum Ribbon Composites Material For Cryogenic Tanks - F33615-99-C-5203
- Structural Amorphous Aluminum For Aerospace Application - F33615-01-2-5217
- Understanding Formation Of Texture, Microstructure And Defects In Titanium Mill Products - F33615-97-C-5273
- Improved Titanium Machining Process - F33615-01-M-5300
- Development Of Ceramic Tool Material And Advanced Multifunctional Coatings for Improved Titanium Machining - F33615-01-M-5301
- Linear Antimony-Based Heterojunction Field Effect Transistor For Microwave - F33615-01-C-5401
- Textured Buffer Layer For The Growth Of High Temperature Superconductor Thin Films - F33615-98-C-5417
- Bulk Gallium Nitride Crystal Growth - F33615-00-C-5420
- Enhanced Sensor Modules - II - F33615-96-C-5469
- Materials and Processes For Multispectral Infrared Detector Arrays - F33615-97-C-5490
- Ruggedized Durable Optical Fiber Connector - F33615-01-M-5500
- Engine Supplier Base Initiative - F33615-95-2-5555
- Shelf-Stable, Low-Temp Cure Epoxy Film Adhesive For On-Aircraft Bonded Repair - F33615-99-C-5602
- Advanced Nondestructive Inspection Techniques Using Data Fusion - F33615-01-M-5607
- Nondestructive Residual Stress Analysis Inspection Method For Critical Engineering - F33615-97-C-5641
- Fullerene-Dendrimer Optical Limiters - F33615-01-M-5703
- Web-Based Design Environment - F33615-99-2-5704
- Simulation-Based Design System For Multi-Stage Manufacturing Processes - F33615-99-C-5709

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OFFICIAL BUSINESS

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